LESSON 18: OVERFISHING AND FISHERIES COLLAPSES

ESSENTIAL QUESTION:

What combination of factors both natural and manmade is necessary for healthy river restoration and how does this enhance the sustainability of natural and human communities?

GUIDING QUESTION:

What factors have led to the collapse of marine fisheries around the world?

OVERVIEW:

This lesson focuses on the recent collapse of marine fisheries across the world due to increased commercial fishing pressures, a result of increased technology coupled with the changing climate of marine environments related to greenhouse gas pollution. Collapsed fisheries include Pacific salmon, Atlantic cod, and Orange Roughy, among others. The collapse of these fisheries has resulted in dramatic shifts in food webs and ecological processes at sea and on terrestrial ecosystems. In addition, it has had major impacts on human coastal communities.

MATERIALS:

- **Lesson 18- Overfishing and Fisheries Collapses.pptx**
- **Lesson 18a- Overfishing and Fisheries Collapses.pdf**
- **The Grand Banks Collapse.doc**
- **Marine Fisheries Management Assignment.pdf**
- Reflection Notes (printable handout)
- Vocabulary notes (printable handout)

PROCEDURE:

1. Review Essential Question; introduce Guiding Question.
2. Students should take a few minutes to respond to the first reflection prompts. Discuss their answers and any questions they've generated.
3. Hand out the Vocabulary Notes. *With this lesson you may want to define the words before presenting the PowerPoint Lesson.*
4. **Present the PowerPoint Lesson**
5. Show charts indicating the increased demand for seafood worldwide, the declines of salmon runs, and the collapse of fish stocks around the world.
6. Have students read the article on the Grand Banks fisheries collapse
7. Marine Fisheries Management Assignment
8. Hand out the second Reflection Journal Page. Give students time for a final reflection the lesson.

ASSESSMENTS:

- **Marine Fisheries Management Assignment.pdf**

WASHINGTON STATE STANDARDS:

SCIENCE

1. **EALR 1: Systems**
2. If the input of matter or energy is the same as the output, then the amount of matter or energy in the system won't change; but if the input is more or less than the output, then the amount of matter or energy in the system will change.
    a. Measure the flow of matter into and out of an open system and predict how the system is likely to change (e.g., a bottle of water with a hole in the bottom, an ecosystem, an electric circuit).
3. **EALR 4: Life Science**
    a. **LS2D** Ecosystems are continuously changing. Causes of these changes include nonliving factors such as the amount of light, range of temperatures, and availability of water, as well as living factors such as the disappearance of different species through disease, predation, habitat destruction and overuse of resources or the introduction of new species.
        i. Predict what may happen to an ecosystem if nonliving factors change or if one or more populations are removed from or added to the ecosystem.
    b. **LS1C** Multicellular organisms have specialized cells that perform different functions. These cells join together to form tissues that give organs their structure and enable the organs to perform specialized functions within organ systems.
        i. Explain the relationship between tissues that make up individual organs and the functions the organ performs.
        ii. Describe the components and functions of the digestive, circulatory, and respiratory systems in humans and how these systems interact.

SOCIAL STUDIES

1. **EALR 5:** The student understands and applies reasoning skills to conduct research, deliberate, form, and evaluate positions through the processes of reading, writing, and communicating.
    a. **Component 5.2:** Uses inquiry-based research.

WRITING

1. **EALR 2:** The student writes in a variety of forms for different audiences and purposes.
    a. **Component 2.1:** Adapts writing for a variety of audiences.
    b. **Component 2.2** Writes for different purposes.

ADDITIONAL RESOURCES AND ENRICHMENT:

http://discovermagazine.com/1995/apr/twilightofthecod489

http://overfishing.org/

http://www.ted.com/talks/sylvia_earle_s_ted_prize_wish_to_protect_our_oceans.html

http://www.ted.com/index.php/talks/capt_charles_moore_on_the_seas_of_plastic.html

This is just amazing

http://www.ted.com/index.php/talks/david_gallo_shows_underwater_astonishments.html

VOCABULARY TERMS:

- **Fisheries-** A fishery is an eco-region and an associated fish population used for commercial fishing purposes. Examples would be the salmon fishery of Alaska or the cod fishery of Newfoundland.

- **Collapse-** When a harvestable species (usually fish) see their population or harvest rate drop to less than 10% of the original figure. It means that harvesting is no longer sustainable and the fish is in danger of economic extinction.

- **Fishfinder sonar-** Fishfinder sonar uses sound waves to detect the location of fish, so that they can be harvested. Sound waves are sent from the ship and reflect off the bodies of fish. The time it takes for the sound waves to return to the ship and the angle of return indicate the distance and location of the fish.

- **Fish Farm-** A facility used to raise commercially viable fish species from egg to adulthood to sell for the market.

- **Aquaculture-** Raising aquatic organisms in contained units for the purpose of producing marketable products. This can include algae, shrimp, oysters, fish, and others.

- **Hatchery-** A facility used to rear juvenile fish for the purpose of stocking rivers or lakes, producing fish for commercial fishing activities, or restoring endangered fish populations

Elwha River Restoration
Overfishing and Fisheries Collapses
Reflection Journal 1

How much fish do you and your family eat? What is your favorite kind of fish to eat and why is it your favorite? How do you like it prepared?

What questions do you have about fish, fishing and fisheries?

Elwha River Restoration
Overfishing and Fisheries Collapses
Vocabulary Notes

Fisheries:

Collapse:

Fishfinder sonar:

Fish Farm:

Aquaculture:

Hatchery:

Elwha River Restoration
Overfishing and Fisheries Collapses
Reflection Journal 2

What do you think we can do to bring fish back to oceans and rivers? Defend your thinking.

What questions or comments do you have about fish, and/or overfishing?

The Grand Banks: Where Have All the Cod Gone? New Scientist 16 Sept 96 p24

Thirty years ago, children in Newfoundland could catch fish by dipping a basket into the ocean. Now Canadian research vessels sweep the seas in vain, finding not a single school of cod in what was once the world's richest fishery. The destruction of the Grand Banks cod is one of the biggest fisheries disasters of all time. And science helped make it happen. The Canadian government banned fishing on the Banks in 1992, when scientists discovered there were nearly no adult cod left. That ban is likely to remain in place for at least a decade. Canada has blamed Spaniards, seals and the weather. But the real damage was done by years of "safe" catches that scientists now realize were just the opposite

How the Banks collapsed

The disaster of the Grand Banks is a compendium of the mistakes made in fisheries all over the world. When scientists began to manage the Banks in the 1950s they promised to assign "safe" quotas to Canadian and foreign fleets. They failed. The cod catch fell from 810,000 tons in 1968 to 150,000 tons by 1977. Canada blamed foreign disregard for quota extended its jurisdiction 200 nautical miles offshore, and evicted the foreigners.

Scientists set catch limits calculated to allow stocks to recover, predicting catches of 400,000 tons by 1990. In anticipation the government helped people in Canada's Atlantic Provinces to buy new boats and fish plants. The bonanza never happened. Every year scientists of the Canadian Department of Fisheries and Oceans (DFO) estimated the size of the fish stocks, and set the "total allowable catch", or TAC, at 16 per cent of the fish, which theory said should allow stocks to increase. But stocks never rose enough to allow TACs greater than 260 000 tons, falling well short of predictions. That wasn't necessarily a disaster, the scientists reasoned. The size of fish populations was held to be dominated by the survival rate of young fish, which varies widely and unpredictably. The slow recovery might simply mean a few bad years. But there were other worrying signs.

The fish were smaller, a sign that each stood less and less chance of surviving the year. And the fleet was fishing a smaller and smaller area of ocean. But the scientists had no means of reacting to any of these portents. They were employed simply to go out every year, collect particular data, estimate stocks and set the year's TACS. Every autumn the DFO research vessel would sail a random course across the Banks, trawling and counting how many fish it caught at different ages, and how long they took to catch, to get data for standard fisheries models. Other data came from the number of fish the commercial fleet caught per hour of fishing. If they caught more fish per hour this year than last, the stock was held to be larger; if fewer, the stock was smaller.

Then in 1989, there was a discrepancy. The commercial data suggested there were twice as many fish as the research data did. The fishermen were catching more fish per hour than the scientists because they were going to warmer patches where they knew cod were congregating. The research vessel, on its random course, was encountering empty ocean. That was the accurate picture. But the scientists were reluctant to favor their data over the fleet's. After all, they made only one cruise; the fleet made hundreds. And they didn't want to believe that the whole theoretical basis for their work was wrong. The error worsened: in 1992, the DFO reported, the area fished had "decreased substantially" since 1987. Tony Pitcher, of the University of British Columbia, says schools of fish such as cod or haddock huddle together in a small area when they are depleted. There, you get a false impression that there are lots of fish, while the surrounding ocean is empty. By contrast, he says, hake eat each other, and thus stay well apart over their range. For hake, catching effort gives a more accurate picture.

The fishing industry stuck with its false impression. The processing company National Sea Products said in 1990 that scientists only thought fish stocks were low because they surveyed large areas of ocean randomly, and didn't "go where the fish are "where they would find that "fishing has never been better". Fishing had never been better, because during the 1980s, aided by subsidies, fishermen bought more powerful boats and new, accurate fish-finding sonar. This was intended precisely to increase the catch per unit effort. Yet scientists took no account of better technology in calculating stock size. So in 1989, the DFO was in a quandary. They lacked confidence in their own data, were reluctant to abandon received wisdom and the region's main employer insisted that fishing was fine. The DFO compromised and decided the stock was midway between the research and commercial data. This was still smaller than they had thought.

Retrospective calculation of the fishing that would have produced such a stock showed boats had been taking not 16 per cent of the fish each year as planned, but at least 60 per cent. The scientists advised a TAC of 125 000 tons, well below the 266 000 of 1988. Then politics took a hand. The fisheries minister refused to anger fishermen by slashing catches that much. Lesley Harris, a former president of Memorial University in Newfoundland who chaired a government inquiry into the fishery in 1990, says the DFO should have insisted. "But scientists being scientists, they weren't prepared to make absolute statements about anything," he says. "Politicians used the uncertainty to set catches as high as possible." This meant 235 000 tons.

In January 1992, the DFO recommended a TAC of 185 000 tons. Then it did another research cruise-and cut that to 120 000. Then in June, it recommended banning fishing altogether. Suddenly, the scientists realized there were no cod old enough to spawn left. By now the fishermen were worried too, and agreed to a fishing moratorium on the Bank and adjacent fisheries. In 1993, it was extended indefinitely.

Lost Jobs

The aftershock of that realization is still being felt, and not only by the thousands of fishermen and fish plant workers who lost their jobs. The death of the Grand Banks has done for the fishing industry what the Antarctic ozone hole did for the chemicals industry: scared everyone out of their complacency. How could an advanced nation with an army of scientists allow one of the richest fisheries in the world to go to be destroyed? And if Canada could do that, what hope is there for the coastal fisheries of Europe, hostage to politics as well as science?

The Grand Banks fell prey to the usual list of suspects: a government that set fishing limits higher than scientists advised; fishermen who cheated on catch quotas; and the lack of restraint that plagues all "open access" fisheries ("if we don't catch them, other boats will"). But press the experts harder and an additional culprit emerges-the scientific models used for estimating sustainable catches. According to those models, the Grand Banks should still be full of fish. Most experts admit the models are inaccurate. Yet only a few seem to realize the seriousness of the error, and even fewer are trying to come up with something better. In the meantime, the models which failed the Grand Banks are being used to govern fisheries around the world.

Daniel Pauly of the International Centre for Living Aquatic Resources Management in the Philippines blames a culture of defensiveness. "It is a commonly held fallacy among fisheries' biologists that only the fishers, or the politicians, are a fault when overfishing occurs," he writes. But "models routinely used by biologists ... induce overfishing". The good news is that at least some researchers are starting to make changes. They now realize that Canada's biologists relied too much on data from commercial catches to estimate the sizes of fish stocks (see "How the Banks collapsed"). Nor was this the only problem.

Canada's biologists also based their assessments of the number of fish it would be safe to catch on two flawed assumptions about fish biology. The central problem is that fish live in the sea. You cannot count them or see how many young fish are coming along for future catches. This problem is compounded by the chaotic way fish reproduce. "Recruitment"-jargon for the number of fish that survive to a catchable state in any one year-varies widely and unpredictably from year to year, and there is no way of measuring it directly.

Time travel

So since the 1950s, biologists have instead caught samples of fish, determined their ages and calculated back in time the populations that would be necessary to produce the observed age profile. Such a model tells you in theory what the recruitment has been, how the size of the stock has changed, and therefore how much fishing you can allow.

But to do this, you need to make some big assumptions. And it's these that are the problem, according to Sidney Holt who studies whaling for the International Fund for Animal Welfare. As a researcher at the British government's fisheries research lab at Lowestoft in the 1950s, Holt helped to develop the Beverton-Holt model, widely used in fisheries to estimate changes in stock sizes based on age profiles. Now he is critical of the simplistic way fisheries' managers have applied the model. And in a message to a conference in Vancouver this year, Holt's former colleague, the late Ray Beverton noted that "there is a strong inverse association between the growth of fisheries science ... and the effectiveness with which it is applied". Part of the problem is that the age profiles of fish populations are not governed by recruitment alone.

They also depend on the death rates of fish, and "the data give you no way to untangle the two", says Holt. So scientists calculate recruitment from age data by assuming that natural mortality is constant and independent of age-and that they know, accurately, what mortality from fishing has been. "But if those assumptions are wrong, your estimate can be wildly off," says Holt. Pauly says this sort of error tends to produce estimates of safe catches that are too big. And if you think managers have applied the model. And in a message to a conference in Vancouver this year, Holt's former colleague, the late Ray Beverton noted that "there is a strong inverse association between the growth of fisheries science ... and the effectiveness with which it is applied".

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Because of another wrong assumption, biologists have been slow to heed this warning signal. They have assumed that no matter how stocks dwindle, there will always be enough adult fish to produce the usual number of young; in other words, that recruitment is unaffected by stock size. This assumption may seem counterintuitive to people accustomed to cats or dogs, or humans, for whom the number of babies depends quite closely on the number of parents. But for natural populations of fish, they do not. "A cod produces eight million eggs," explains Lesley Harris, a former president of Memorial University in Newfoundland, who chaired an inquiry into the fishery in 1990. "Only a tiny fraction survive.

A tiny difference in that survival rate makes huge differences to the resulting number of fish, far more difference than comparatively small variations in the number of parents." Most fisheries scientists have assumed that this condition always holds. But Holt says that "even in the 1950s, we knew it didn't and that this could cause problems". As stocks dwindle there comes a point where smaller numbers of adult fish do cause recruitment to fall, perhaps because the total number of eggs laid ceases to be so massively in excess of the numbers that survive, perhaps because the presence of fewer adults exposes the young to more predation.

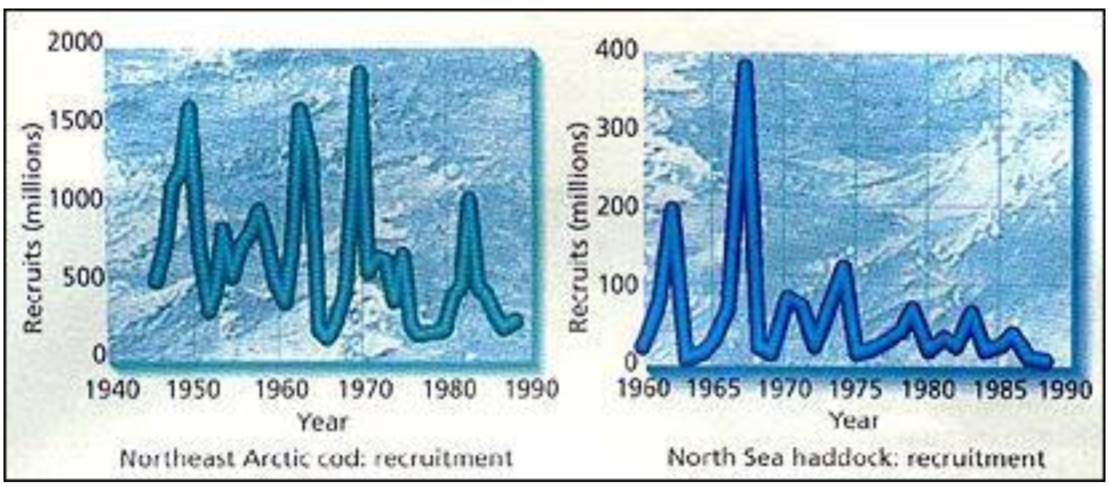
But whatever the reason, recruitment falls when fishing pressure is intense (see Figures). "If the assumption that recruitment is independent of stock size is applied to depleted stocks-as has commonly been done-then sustainable catches will be grossly overestimated," says Holt. This is because of a knock-on effect in successive years: fishing reduces the spawning stock, which reduces recruitment, which reduces the spawning stock, and so on. If you assume that recruitment will fall within its natural range whatever happens, and replenish the stocks accordingly, you will continue to permit these catches, thinking that you are only having a "few bad recruitment years". Instead, the stock can disappear. And this is precisely what happened on the Grand Banks. But fisheries' managers have yet to change their ways.

If recruitment declines over a number of years, they still attribute it to unpredictable but natural variations, rather than suspecting excessive catches. "Until about two years ago, we didn't realize the importance of the spawning stock," says Henrik Sparholt of the International Council for the Exploration of the Seas, an intergovernmental body, based in Copenhagen, which recommends catch limits to many governments. Sparholt blames governments, which regularly set allowable catches higher than the ICES recommends, for the fall in European stocks, not faulty science. Yet he admits that many stocks in Europe may be at or below the threshold where recruitment depends on stock size. This means that overfishing could continue even if scientific advice is heeded because the advice may be wrong. And once depleted, a fishery may not always recover. Other species may fill the ecological niche of the former fish, and keep the recovering stock from resuming its previous place in the ecosystem.

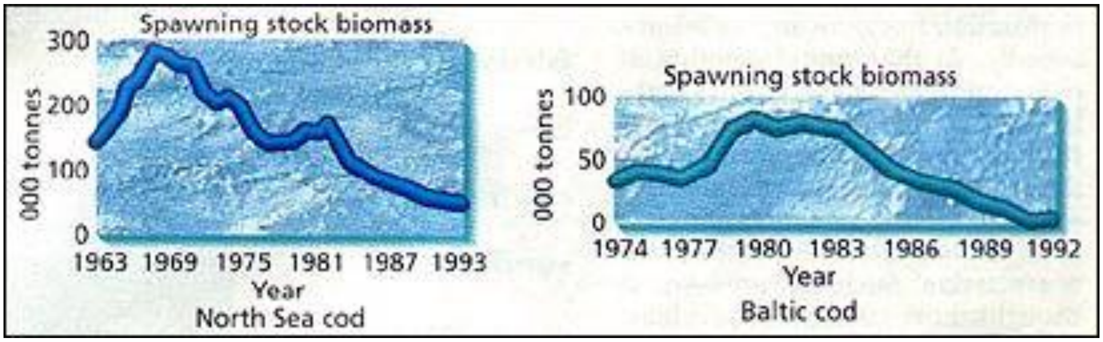
A commercial fish called the slipmouth was replaced by squid in the Gulf of Thailand, says Pauly; back on the Grand Banks, yellowtail flounder "may not come back", says Harris, while the haddock population wiped out in the 1950s "has never recovered". The belief that everything depends on yearly recruitment means that virtually all fisheries are managed on a yearly basis, with no long-term planning. Why plan if your resource depends on unpredictable yearly fluctuations? And why worry unduly about overfishing if even a small spawning stock can in theory bring the population back? "History shows a long term drop in recruitment after overfishing in every single case," says Harris. "It's been true of herring, redfish, haddock, cod, flounder, American plaice, and Greenland halibut."

It is time to stop ignoring the evidence, he says. Yet few scientific dogmas have been as difficult to dislodge as the notion that the number of fish produced has nothing to do with the number available to breed. "It has been extraordinarily difficult to dissuade fisheries biologists from applying simple formulas like recipes and getting half-baked answers," says Holt. In their defense, biologists may not realize what a big difference such critical assumptions make to the success of their models, because they have never tested them. You can't test ecological models by running varying versions of the real world.

It was the experimental use of modeling for evaluating whale management proposals that convinced Holt. He is one of a handful of scientists advocating simulation as a tool to find management procedures that work. The key, he says is to avoid basing your catch estimate on population models that rely on making assumptions about immeasurable variables. Nor should you assume that you can accurately measure the stock "You might conclude that it's safe to catch 20 whales this year, and do the same next year and the next," says Holt "But given the difficulty of counting whales, if that catch is too high, then by the time its cumulative effects show in stock assessments, the stock might have already been badly damaged." The same applies to fish. How do you avoid either assumption? You take your computer fishing. "You start with a hypothetical population of fish, about which you know only its size an estimate of the statistical error of that value, and its catch history," says Holt. This is information scientists can actually collect. "Then, you invent an algorithm and management procedure, with which given what you know about the population, you calculate a safe catch limit.



There is nothing special about such algorithms, says Holt, although they can be very complex, changing the permitted catch according to a host of measurable factors that influence fisheries, depending on the type of information available. It may use information about how much fishing effort is required to catch fish, for example, or it may not. The point is that whatever your method for calculating catches, you test it. You run a simulation, where you use the same method year after year, and see whether it crashes your stock. Then you repeat the simulation, imposing different conditions each time. What if the stock is really half what you think? What if the algorithm says we should cut fishing if the spawning stock falls beneath a certain level, but it really should be another level? "And you run it again," says Holt, "and see if your management procedure is conservative enough to keep the stock from crashing even if you're wrong."

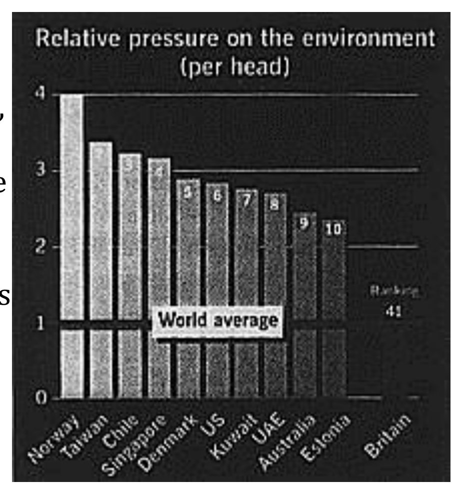


This allows the setting of long-term goals, such as maximizing yield while keeping the risk of depletion to agreed levels. "We can achieve sustainability without significant risk of inadvertent depletion, and reasonably high-but certainly not theoretically maximal catches in the long run," says Holt. That would suit the fishing industry, says Peter Spohr, head buyer for Nordsee, Europe's largest fish processor. "We .prefer a predictable catch to the feast or famine we have now."

Sorry plight

Efforts to apply computer simulation to European fisheries are being made at the British government's fisheries labs in Lowestoft. Such research could help to form long-term fisheries goals, which the European Commission was given the power to propose in 1992. So far, the European Union's fisheries ministers have not agreed even to modest proposals. Scientists remain among the obstacles. There is immense resistance to admitting that the methods are flawed and few scientists want to discuss work on new approaches, such as computer simulation. One who did not wish to be named said that "it would imply that what we are doing now is wrong". Some believe the sorry plight of the Grand Banks has already proved that. "The population crashed faster than I thought possible in 1990, and I was a pessimist," says Harris. "The northern Banks are a desert. Cruises in the past two years have found no cod at all."

Trashing the Planet NS 3 Oct 98 12



NORWEGIANS, who pride themselves on their green credentials, are the most environmentally destructive people on Earth, says a report published this week by the World Wide Fund for Nature (WWF) in Geneva. The report estimates the pressure that nations put on global ecosystems by their exploitation of four key natural resources grain, marine fish, wood and freshwater as well as their contribution to global warming through carbon dioxide emissions and their consumption of land, measured by cement production. Per head of population, a Norwegian puts four times as much pressure on the environment as the average global citizen-and 50 per cent more than either Americans or Australians.

The country's worst offence, says Jonathan Loh, the compiler of the index, is its consumption of marine fish. Per person, Norway catches 250 kilograms of marine fish each year, more than 10 times the world average. Much of it is not eaten directly, but fed to salmon on fish farms around the coast. The citizens of Taiwan, Chile, Singapore and Denmark, all major fish consumers, are the worst offenders after Norway. The US, Australia, Kuwait and Canada also appear in the top 12. Britain lies in 41st place, while Bangladeshis have the least impact on the environment. "It would of course be possible to obtain different results by applying different weightings to different components in the index," says Loh. Alex MacGillivray of the London-based New Economics Foundation, which gathered data for the report, points out that environmental indicators can never be perfect (see Editorial, 4 April, p 3). "There is always a subjective element in what you decide to include and how you weigh the different elements," he says. "But they do serve a role in highlighting environmental villains and ecological pressures, some of them unexpected.

The Norwegians are one example." The Norwegian government this week defended its environmental record. Paul Hofseth, special adviser to the environment ministry in Oslo, says: "We only use half of the timber that grows in our country each year. And we believe we make sustainable use of our marine fish. I can't see how that damages the global environment." Other villains emerge within the other five indicators. Americans use twice as much grain as the average citizen, 692 kilograms per head per year. Swedes use the most wood, 2.3 cubic meters - almost four times the global average. And the four biggest consumers of freshwater are the central Asian republics that drain the Aral Sea to irrigate their cotton fields. The WWF report also looks at the world's key ecosystems: forests, freshwater and the marine environment. All are in decline, but freshwater ecosystems came out worst. Numbers of 200 vertebrate species used as indicators of freshwater health fell by half. Altogether, the report concludes that the health of the world's ecosystems has declined by 30 per cent in 25 years. Fred Pearce

Marine Fisheries Management, History, Techniques, and Impact Unit

Use the internet and maps to answer the following questions

1) Name the top 5 consumers of fish per capita in the world.

1 _______________

2 _______________

3 _______________

4 _______________

5 _______________

2) The locations listed below are the greatest fisheries in the world for total fish production. For each location, examine a map and describe what geographical and ecological features they share in common.

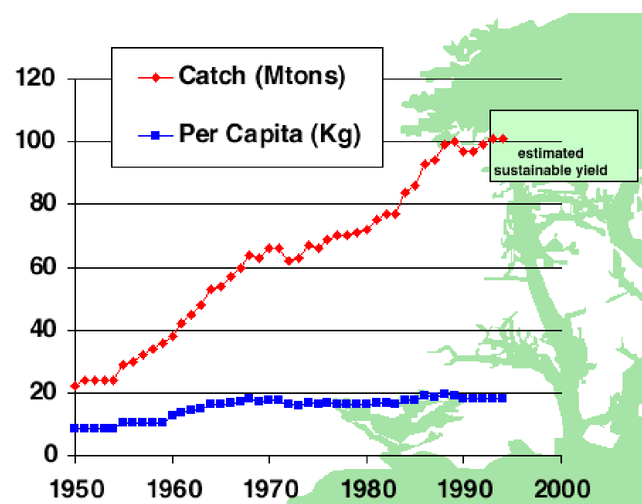
North Sea	*Grand Banks (near Newfoundland)*	*Gulf of Alaska*	*New Zealand*	*Sea of Okhotsk*

3) The average American eats __________ pounds of fish per year (per capita).

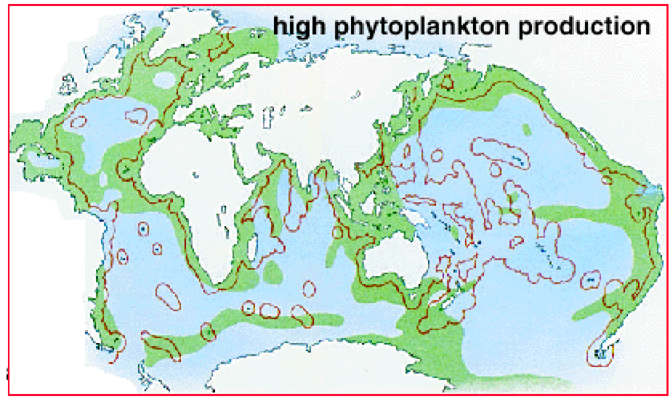
4) One in ten fish caught is eaten in ________________.

5) Marine sources represent ________ % of the world's protein consumption.

6) Look at the graph. Explain what this data represents.



7) Examine the map below. Green areas represent areas of high productivity. Name three areas
8) where there would be large fish stocks without government claims?



human claims

Source: Gaia: An Atlas of Planet Management

9) Examine the table below.

Species	Peak Year	Peak Catch	1992 Catch	Percent Change
Pacific herring	1964	0.7	0.20	-71%
Atlantic herring	1966	4.1	1.50	-63%
Atlantic cod	1968	3.9	1.20	-69%
So. African Sardines	1968	1.7	0.10	-94%
Haddock	1969	1.0	0.20	-80%
Peruvian anchovy	1970	13.1	5.50	-58%
Polar cod	1972	0.35	0.02	-94%
Cape hake	1972	1.1	0.20	-82%
Silver hake	1973	0.43	0.05	-88%
Yellow croaker	1974	0.20	0.04	-80%
Atlantic redfish	1976	0.7	0.30	-57%
Chub mackerel	1978	3.4	0.90	-74%
So. American Sardines	1985	6.5	3.10	-52%
Alaska pollock	1986	6.8	0.50	-26%
North Pacific hake	1987	0.30	0.06	-80%
TOTALS (in millions)	**---**	**51.48**	**21.77**	**-58%**

a) What is the most caught fish in the world?

b) Which fish have seen the greatest total decline in catch since their peak?

c) Which fish have seen the great percentage in decline since their peak?

d) Which fish has seen the least decline?

10) Explain what aquaculture is and what effects it may have on overfishing.

11) Give 5 species of fish that are commonly harvested via aquaculture. Has the use of aquaculture reduced the declines of these species in the wild?

12) What are the risks/disadvantages of the use of aquaculture? Give a minimum of three and explain why.